

Scientific Article

Two-and-a-half-year clinical experience with the world's first magnetic resonance image guided radiation therapy system

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Abstract

Purpose: Magnetic resonance image guided radiation therapy (MR-IGRT) has been used at our institution since 2014. We report on more than 2 years of clinical experience in treating patients with the world's first MR-IGRT system.

Methods and materials: A clinical service was opened for MR-IGRT in January 2014 with an MR-IGRT system consisting of a split 0.35T magnetic resonance scanner that straddles a ring gantry with 3 multileaf collimator-equipped ⁶⁰Co heads. The service was expanded to include online adaptive radiation therapy (ART) MR-IGRT and cine gating after 6 and 9 months, respectively. Patients selected for MR-IGRT were enrolled in a prospective registry between January 2014 and June 2016. Patients were treated with a variety of radiation therapy techniques including intensity modulated radiation therapy and stereotactic body radiation therapy (SBRT). When applicable, online ART was performed and gating on sagittal 2-dimensional cine MR was used. The charts of patients treated with MR-IGRT were reviewed to report on the clinical and treatment characteristics of the initial patients who were treated with this novel technique.

Conflicts of interest: Benjamin Fischer-Valuck, Lauren Henke, Olga Green, Rojano Kashani, Jeffrey Bradley, Cliff Robinson, Maria Thomas, Imran Zoberi, Jiayi Huang, Jeff Olsen, Parag Parikh, Sasa Mutic, and Jeff Michalski have received either a grant, honorarium, speaker's bureau, or travel expenses reimbursement from ViewRay Inc. outside the scope of this report.

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Results: A total of 316 patients have been treated with the MR-IGRT system, which has been integrated into a high-volume clinic. The cases were most commonly selected for improved soft tissue visualization, ART, and cine gating. Seventy-six patients were treated with 3-dimensional conformal radiation therapy, 146 patients with intensity modulated radiation therapy, and 94 patients with SBRT. The most commonly treated disease sites were the abdomen (28%), breast (26%), pelvis (22%), thorax (19%), and head and neck (5%). Sixty-seven patients were treated with online ART over a total of 244 adapted fractions. Cine treatment gating was used for a total of 81 patients.

Conclusions: MR-IGRT has been successfully implemented in a high-volume radiation clinic and provides unique advantages in the treatment of a variety of malignancies. Additional clinical trials are in development to formally evaluate MR-IGRT in the treatment of multiple disease sites with techniques such as SBRT and ART.

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Introduction

Magnetic resonance (MR) image guided radiation therapy (IGRT) represents a treatment modality that offers potential solutions to the well-recognized challenges of radiation delivery. Compared with computed tomography (CT)-based strategies, MR imaging (MRI) for treatment guidance offers superior soft tissue definition that is potentially advantageous in numerous disease sites.¹ From a patient-safety perspective, daily image guidance with MR also avoids undesirable radiation exposure inherent to the use of CT imaging guidance such as cone beam CT (CBCT). Moreover, cine MRI can be safely employed throughout a patient's entire treatment fraction and course to monitor and manage intrafraction motion. MR-IGRT enables daily imaging of sufficient quality to permit daily plan adjustments in response to interfraction changes in anatomy.² This approach is valid even in disease sites that are typically poorly visualized with conventional x-ray imaging, such as soft tissues within the abdomen and pelvis.¹ This daily plan adjustment, termed online adaptive radiation therapy (ART), has been found in dosimetric studies to potentially improve the therapeutic ratio of radiation therapy (RT) by enhanced sparing of organs-at-risk (OARs) and safe-dose escalation in disease sites where high-dose therapy has been limited.^{3,4} Thus, MR-IGRT has the potential to improve the accuracy, precision, and safety of RT delivery.

Historically, MR-IGRT has been unavailable due to the challenges of protecting a radiation delivery device from the influence of a magnetic field and maintaining imaging quality in the presence of a treatment device. At our institution, the world's first commercially available device for MR-IGRT was clinically developed and implemented in routine clinical practice (MRIdian System; ViewRay Inc., Oakwood Village, OH). In the more than 2 years after the first patient treatment in January 2014, more than 300 patients have been treated in disease sites such as head and neck, breast, thorax, abdomen, and

pelvis. In this study, we review our institutional experience with patients who were treated on the world's first MR-IGRT system. More specifically, we aim to describe our initial clinical experience and the integration of this new technology within a high-volume clinical practice, highlight the technical capabilities of the system, and describe the selection of patients who benefited most from MR-IGRT.

Methods and materials

Setting and patients

The radiation oncology department at our institution includes 21 attending radiation oncologists who service our main site and 5 additional satellite locations. The main facility includes 7 linear accelerators with a dedicated MR simulator, a Gamma Knife Perfexion (Elekta, Stockholm, Sweden), a single-gantry proton therapy system (Mevion, Littleton, MA), a cobalt 60-based MR-IGRT system (ViewRay Inc., Oakwood Village, OH), and a full brachytherapy suite. A linear accelerator-based MR-IGRT system is currently under construction. Our satellite facilities have an additional 7 linear accelerators. In 2015, approximately 3,400 patients were treated with external beam radiation therapy at our facility.⁵

All patients included in this study were enrolled in an institutional review board-approved prospective registry, and informed written consent for treatment was obtained. Patients were divided into groups on the basis of the anatomical site of the malignancy and the treatment technique (stereotactic body radiation therapy [SBRT], adaptive, gating). Additionally, the clinical rationale with regard to the selection of MR-IGRT compared with conventional linac-based treatment was evaluated (ie, improved soft tissue imaging, cine gating on the basis of daily anatomy, and online/offline adaptation) when available.

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